REMARKS

Claims 10-12, 18, 19 and 21 have been rejected under 35 U.S.C. §102(b) as anticipated by Van Dine et al (U.S. Patent No. 5,573,866), while Claims 10-22 have been rejected under 35 U.S.C. §102(e) as anticipated by Hornburg et al (U.S. Patent No. 5,981,096). In addition, Claim 23 has been rejected under 35 U.S.C. §103(a) as unpatentable over McElroy (U.S. Patent No. 4,795,683). However, for the reasons set forth hereinafter, Applicants respectfully submit that the claims which remain of record distinguish over all of the cited references, whether considered separately or in combination.

The present invention is directed to a method and apparatus for cooling and controlling the operating temperature of a fuel cell stack in a so-called direct-methanol fuel cell system. In such systems, an aqueous methanol solution is reacted on the anode side of the fuel cell, eliminating the need for evaporation and reforming of the liquid methanol, as is commonly used in other types of fuel cell systems.

The fuel cell system according to the invention is cooled by providing a proton conducting membrane 16 which separates the cathode chamber from the anode chamber, and which is made of a material such as nafion®, through which water molecules bound to protons that migrate through the membrane can pass. Water which penetrates through the membrane in liquid form in this manner is

evaporated in the cathode chamber by the hot process gas therein, and the evaporation process cools the fuel cell.

According to the invention, the temperature within the fuel cell is adjusted by regulating either the rate at which the liquid fuel/coolant mixture is supplied to the anode chamber of the fuel cell, or the operating pressure within the cathode chamber. By regulating either or both of these two quantities, it is possible to set and maintain a desired operating temperature within the fuel cell system. See page 2, line 33 - page 3, line 11; page 8, lines 6-18; and page 8, line 32 - page 9, line 4.

The latter feature of the invention is recited in independent Claims 1, 21 and 23 of the application. In particular, Claim 1 recites "means for setting and maintaining a desired operating temperature in said fuel cell by adjusting at least one of pressure in said cathode compartment and a rate of delivery of the liquid coolant/fuel mixture to said anode compartment." Claims 21 and 23 are method claims which are similarly limited.

The Van Dine et al reference discloses a PEM fuel cell in which the fuel is provided to the anode chamber in the form of a mixture of liquid methanol and water. The electrolyte membrane which separates the cathode chamber from the anode chamber may be made, for example of a conventional nafion® film, so that cross-over water passes with the methanol, through the polymer electrolyte into the cathode chamber where it is evaporated, and cools the cathode side of each cell in the stack.

The Van Dine et al reference differs from the invention as defined in Claims 10 and 21, however, in that it contains no discussion of setting and maintaining the operating temperature within the fuel cell at a desired level by controlling the pressure in the cathode chamber or the flow rate of the liquid fuel/coolant mixture to the anode chamber. (In Claim 10, the latter limitation has been rewritten in the form of means plus function under 35 U.S.C. §112, sixth paragraph, is entitled to be given weight.) With regard to this feature of the invention, the Office Action states at page 3 that the fan 26 is deemed to provide positive pressure to the cathode compartment so as to cool the chamber. Furthermore, with regard to the delivery rate for coolant/fuel mixture, the Office Action refers to Column 4, line 5 of the specification which states that the methanol metering pump 20 can selectively be operated and controlled, and to Column 4, line 36 which states that the use of water methanol mixture allows the stack to be operated at higher temperatures without it risking electrolyte dry out.

While the Van Dine et al reference recognizes and takes advantage of the cooling effect which results from the evaporation of cross-over water into the cathode chamber, in order to cool the fuel cell, it contains no discussion or recognition of the possibility of adjusting and maintaining the operating temperature within the fuel cell at a desired level by adjusting either or both of the flow rate at which the liquid methanol/coolant mixture is supplied to the anode or the operating pressure within the cathode.

The Hornburg et al reference, on the other hand, discloses a fuel cell system which is similar to the present invention in its overall layout, and its use of a liquid fuel/coolant mixture. However, in Hornburg et al the cathode exhaust gas is cooled by means of a heat exchanger, as noted at Column 4, lines 27-29. Accordingly, as with Van Dine et al, nothing in Hornburg et al teaches or suggests the method according to the present invention, in which the operating temperature of the fuel cell is set and maintained at a desired value by adjusting the flow rate of the liquid fuel/coolant mixture or the operating pressure in the cathode chamber.

The McElroy reference discloses an evaporatively cooled fuel cell in which liquid water migrates from the anode chamber to the cathode chamber for cooling purposes. (See Column 2, lines 49-51; Column 4, lines 22-26.) However, like both Van Dine et al and Hornburg et al, McElroy contains no teaching or suggestion of setting and maintaining a desired operating temperature in the manner recited in Claim 23. Furthermore, it is noted that the McElroy apparatus appears to operate with a gaseous hydrogen fuel, in which liquid water is introduced into the fuel stream in the form of a mist. (See Column 3, lines 30-33.) With regard to this aspect of the apparatus, the Office Action states that since both the hydrogen gas and the liquid water are introduced into the anode compartment, a skilled artisan would find it obvious that both components would form a mixture in the form of humidified hydrogen gas. However, if this were so, the apparatus in McElroy would not work, since the water could mix with the hydrogen to form a humidified mixture only after it has evaporated.

But, as noted at Column 2, lines 61-63, in order to achieve the desired cooling effect, the water vapor must be supplied in the liquid phase rather than the vapor phase, because without a phase change, no heat would be lost from the system and the evaporation of the water would not cool the cell.

In light of the foregoing remarks, this application should be in condition for allowance, and early passage of this case to issue is respectfully requested. If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #1748X/49135).

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

Please amend the claims as follows:

10. (Amended) A fuel cell system, comprising:

1) at least one fuel cell which has

a) an anode compartment,

b) a cathode compartment, and

c) a proton-conducting membrane which separates said anode compartment from said cathode compartment and is capable of allowing water to pass;

2) a cathode circuit in which said cathode compartment is disposed, [and] said cathode circuit further [includes] including a cathode feeder for delivering oxygen-containing gas to said cathode compartment; and

3) an anode circuit in which said anode compartment is disposed, [and] said anode circuit further [includes] including a gas separator, and an anode feeder for delivering a liquid coolant/fuel mixture to said anode compartment, [and a pump for pumping the liquid coolant/fuel mixture to said anode compartment, wherein] whereby cooling [the coolant/fuel mixture

circulating] in the anode circuit is effected by [the fuel cell which is designed for an operation involving water passing] evaporation of liquid coolant that passes through said membrane from the anode compartment into the cathode compartment; [,] and [in that an]

4) means for setting and maintaining a desired operating temperature [of the] in said fuel cell [is set] by [controlling] adjusting at least one of pressure [of] in said cathode compartment, and a rate of [or the] delivery of the liquid coolant/fuel mixture [from said pump.] to said anode compartment.

21. (Amended) A method of operating a fuel cell system having at least one fuel cell which includes an anode compartment and a cathode compartment which are separated from one another by a proton-conducting membrane, and an anode feeder for delivering a liquid coolant/fuel mixture to the anode compartment, comprising:

setting the operating temperature of the fuel cell by controlling one of pressure of the cathode compartment and [a] volume flow of the coolant/fuel mixture into the anode compartment;

passing water through the proton-conducting membrane from the anode compartment into the cathode compartment; and

cooling the coolant/fuel mixture in the anode compartment.

23. (Amended) A method of [cooling a coolant/fuel mixture provided to] controlling an operating temperature of a fuel cell system having at least one fuel cell that includes an anode compartment and a cathode compartment which are separated from one another by a proton-conducting membrane, and an anode feeder for delivering a liquid coolant/fuel mixture to the anode compartment, comprising:

passing [water] coolant through the proton-conducting membrane from the anode compartment into the cathode compartment; [and]

evaporating the [water] coolant passing into the cathode compartment, whereby the evaporation of the water cools the coolant/fuel mixture in the anode compartment; and [.]

setting and maintaining a desired operating temperature in said fuel cell system by adjusting at least one of a flow rate of the liquid coolant/fuel mixture, and pressure in the cathode compartment.